SASKATCHEWAN RESEARCH COUNCIL

COPPER AND MOLYBDENUM LEVELS IN FORAGE PLANTS GROWING ON COAL SPOILS IN SOUTHEASTERN SASKATCHEWAN

by

Z.M. Abouguendia
R.C. Godwin

SRC Technical Report No. 154

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SUMMARY

The main objective of this study was to determine the status of copper and molybdenum in forage plants growing on coal spoil materials in southeastern Saskatchewan where copper deficiency was previously suspected. The study involved sampling of six plant species at three locations: Bienfait, Roche Percee and Estevan.

The copper (Cu) values reported here are generally lower than those for forage plants growing on nonmined agricultural land and are near or below the minimum cattle nutritional levels. Both white and yellow sweetclover exhibited molybdenum (Mo) levels exceeding the upper limit tolerated by cattle. The high molybdenum levels combined with the low copper levels resulted in abnormally low Cu:Mo ratios, generally less than 2:1. Ratios of less than 2:1 are likely to cause metabolic imbalances, called molybdenosis, to develop in cattle. The problem may be minimized by avoiding the use of Mo accumulating plant species in revegetation, by integrating the use of reclaimed areas with adjacent undisturbed areas, or by using trace-mineralized salts containing adequate levels of copper.

However, the available Cu levels in the spoil materials analyzed are adequate for plant growth and the Mo levels obtained are not toxic to plants.

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1 INTRODUCTION AND OBJECTIVES

Thick surface-minable coal zones in southern Saskatchewan are found under 390,000 ha (960,000 acres) of agricultural and range land. Almost one section of land (260 ha or 640 acres) is disturbed each year as a result of strip mining for coal in the province. Most of the present production of coal comes from the Estevan region (Figure 1.1).

Saskatchewan Environment is currently developing guidelines (presently available in a draft form) to be applied to strip-mined coal lands in Saskatchewan (Mcleod 1982). According to these guidelines, mining companies will be required to return the land to a productivity level which is at least equal to the original productivity. One of the main reclamation criteria indicated in the guidelines is the establishment of a self-sustaining vegetation cover, mainly for grazing by livestock and wildlife.

Saskatchewan Research Council, jointly with Saskatchewan Environment, conducted a preliminary evaluation of revegetation potential of coal spoils in the Estevan area in 1982. The preliminary data indicated elevated levels of molybdenum in white sweetclover (Melilotus alba) growing on coal spoils. In addition, the copper levels were unusually low. The Cu:Mo ratio found was sufficiently low to cause molybdenosis, a serious nutritional imbalance disease, in grazing ruminants. However, the data on white sweetclover are rather limited and of preliminary nature and cannot provide the basis for an adequate evaluation of the potential problem in the strip-mined area in southeastern Saskatchewan.

The main objective of this study was to determine the status of Cu and Mo in the main forage plants growing on coal spoil materials in southeastern Saskatchewan.

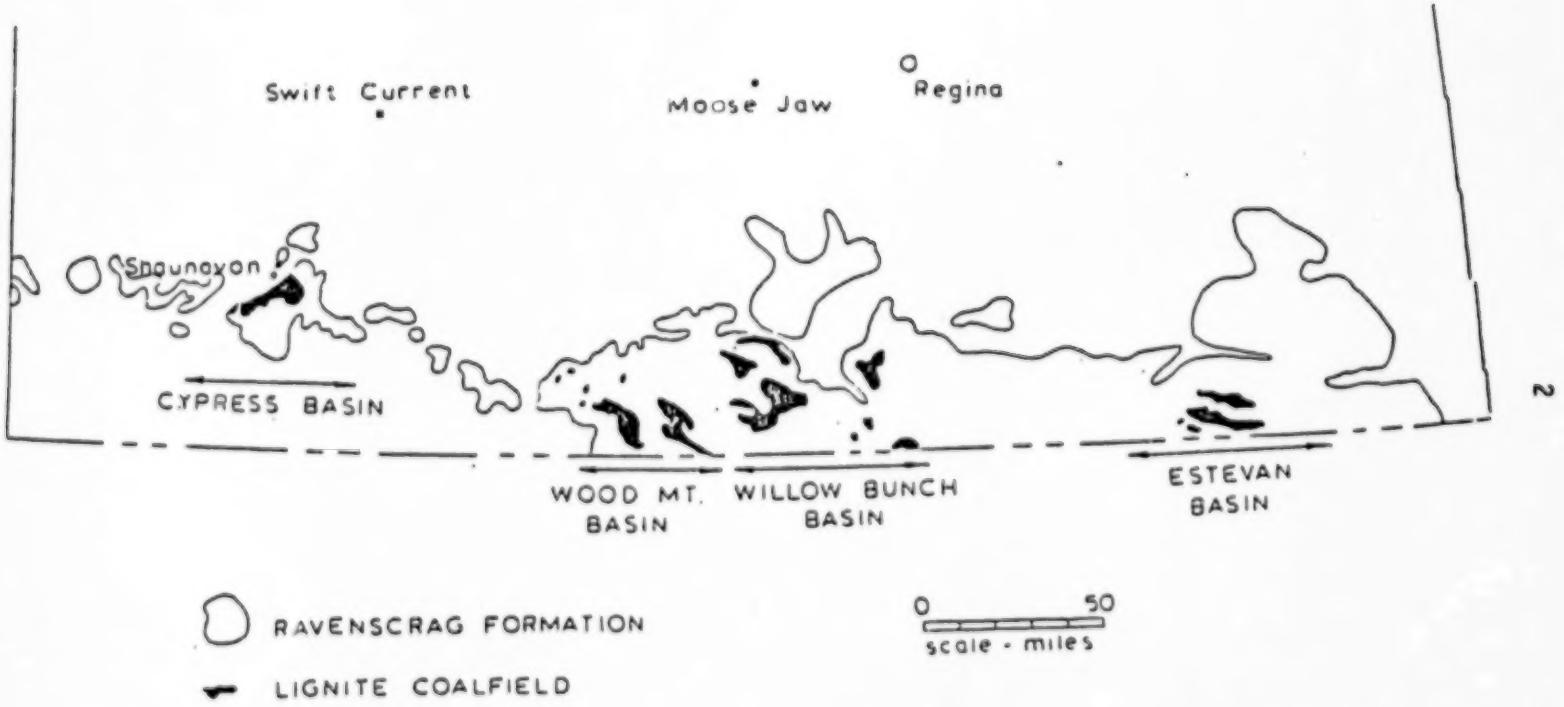


Figure 1.1 Distribution of Coal Resources in Southern Saskatchewan. (Saskatchewan Department of Mineral Resources 1978).

2 METHODS

2.1 Study Region

Three locations were selected (Figure 2.1) for sampling of plant and spoil material:

(1) Bienfait

(2) Roche Percee

(3) Estevan

The study region is located near the southern limit of the Cold "Forest" Climatic Zone of Saskatchewan (Chakravarti 1969). The summers are cool with mean daily July temperature between 15.7^{o} and 19.0^{o}C, and winters are cold with mean daily January temperature between -15.7 and -20.7^{o}C. The mean annual number of frost-free days is estimated to be 100 days. The mean annual precipitation is 410 mm. The May to September precipitation amounts to approximately two-thirds of the total annual precipitation. The 1983 season was drier and hotter than normal.

The soils of the region are predominantly Dark Brown Chernozemic. The potential natural vegetation of the upland is a mixed-prairie grassland dominated by the Spear Grass-Wheatgrass (Stipa-Agropyron) Association.

2.2 Field Sampling

Field sampling was conducted in early July, 1983. Four composite samples of the aboveground parts of the dominant forage plants were randomly collected at each location. The material was clipped as close to ground level as possible. Occasionally only two samples were collected. Species sampled included:

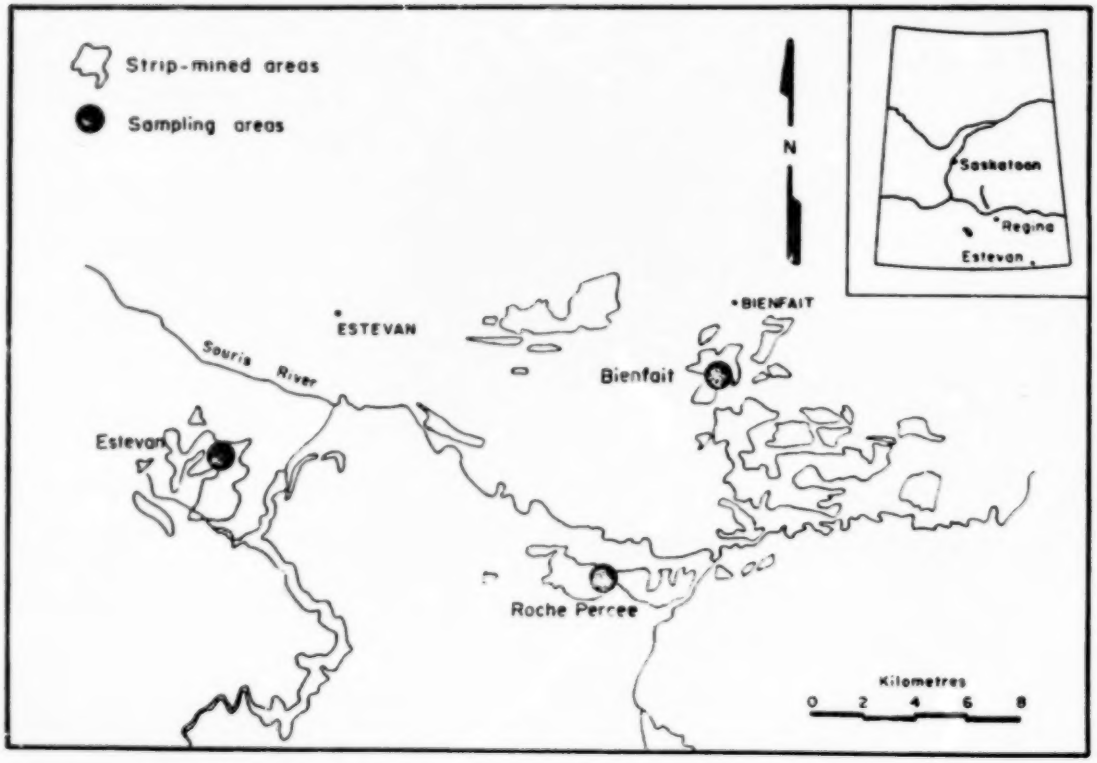


Figure 2.1 Location of the Sampling Areas.

Legumes

(1) Alfalfa (Medicago Sativa L.)

(2) White sweetclover (Melilotus alba Medic.)

(3) Yellow sweetclover (Melilotus officinalis (L.) Pall.)

Grasses

(1) Smooth brome (Bromus inermis Leyss.)

(2) Crested wheatgrass (Agropyron cristatum (L.) Gaertn.)

(3) Russian wildrye (Elymus junceus Fisch.)

Growth stages of the species sampled are given in Table 2.1, while a general indication of the abundance of these species on the coal spoils in the area is given in Table 2.2.

The plant samples were air-dried at room temperature prior to sending to the Saskatchewan Research Council Analytical Facility for analysis for determination of Cu and Mo levels.

A total of 24 composite samples of spoil material were obtained from the same locations where plant material was collected. The samples were taken to a depth of 30 cm. The material was air-dried prior to shipping to the Saskatchewan Soil Testing Laboratory for determination of Cu and Mo levels.

2.3 Plant and Soil Analysis

Plant samples were oven-dried at $70^{o}C$ and then broken into small pieces. A 5 g sample was digested with 200 mL of nitric acid and 6 mL of perchloric acid. Concentrations of Cu and Mo were then determined using ICP (inductive coupling plasma) by the Atomic Emission Spectroscopy Technique. Concentrations are reported on dry-weight basis of plant

Table 2.1 Growth Stages of the Plant Species Sampled.

Species	Locations		
	Bienfait	Roche Percee	Estevan
Smooth brome	vegetative, regrowth after grazing	seed setting	
Crested wheatgrass	vegetative, regrowth after grazing		seed setting
Yellow sweetclover	vegetative, regrowth after grazing	late bloom	late bloom
Russian wildrye	vegetative, regrowth after grazing		
Alfalfa		late bloom	late bloom
White sweetclover		bloom	bloom

Table 2.2 Frequency of Occurrence of the Species Sampled as Reported in a Survey of Coal Spoils in the Region by Anderson et al 1977.

Species	No. of Sites*	Average Frequency (%)
White and yellow sweetclover	20	34
Smooth brome	15	15
Crested wheatgrass	1	4
Alfalfa	4	1
Russian wildrye	N/A**	N/A**

* Out of 23 sites.
** Not available.

material.

Determination of available molybdenum in the soil involved extraction of Mo with an anion exchange resin (Dowex 2-4X, chloride form) (Bhella and Dawson 1972). The molybdate was leached from the resin with 10% NaCl. The resultant extract was analyzed colorimetrically using the potassium thiocyanate procedure (Reisenaur 1965).

Available soil copper was determined using the DTPA extraction procedure described by Lindsay and Norvell (1978). The procedure consisted of shaking 10 g of air-dry soil with 20 mL of extractant for two hours. The leachate was filtered, and Cu concentration was measured in the filtrate by atomic absorption spectrophotometry.

Soil pH was determined using a glass electrode in a $CaCl_2$ (0.01 N) soil suspension (10:1). Texture was estimated manually.

Statistical analysis included analysis of variance. All significant tests were conducted at the 0.95 level of probability.

3 RESULTS AND DISCUSSIONS

3.1 Copper Levels in Plants

Copper levels in plants ranged from 2.4 to 6.2 µg/g (Tables 3.1 - 3.3, Figure 3.1). Statistical analysis of the data showed no significant differences in species copper levels among locations. Interspecific differences, however, were noted within each of the three locations sampled. Copper levels in legumes (alfalfa, white and yellow sweetclover) were generally higher than those in grasses (smooth brome, crested wheatgrass and Russian wheatgrass). However, the levels for alfalfa are below the 9 µg/g level, indicating copper deficiency (Karamanos 1984).

The copper levels found in this study are near or below the minimum cattle nutritional levels of 4-5 µg/g of dry diet (U.S. National Research Council 1976; Cullison 1979). However, it should be noted that Cu concentration is only one of several factors governing the Cu status of cattle.

The Cu levels obtained in this study are generally lower than those of forage plants grown on undisturbed agricultural land in east central Saskatchewan (Stewart et al 1979).

3.2 Molybdenum Levels in Plants

Molybdenum levels in plants showed greater variation than Cu levels, ranging from 2.1 to 13.8 µg/g (Tables 3.4 - 3.6, Figure 3.2). No statistical significant differences were found in species Mo levels among location, with the exception of white sweetclover. Mo levels in white sweetclover from Roche Percee were significantly higher than those from the Estevan location.

Table 3.1 Copper Levels (µg/g) in Forage Plants Growing on Coal Spoils in the Bienfait Area. (Detailed data can be found in Appendix A.)

Species	No. of Samples	Mean	Standard Deviation	Standard Error (SE)	SE as % of Mean	Confidence Limit*
Brome	4	3.3	0.29	0.14	4.2	0.45
Crested wheatgrass	4	2.4	0.44	0.22	9.2	0.70
Yellow sweetclover	4	6.2	0.65	0.32	5.2	1.02
Russian wildrye	4	2.4	0.50	0.25	10.4	0.80

*At the 0.95 level.

Table 3.2 Copper Levels (µg/g) in Forage Plants Growing on Coal Spoil Material in the Roche Percee Area. (Detailed data can be found in Appendix A.)

Species	No. of Samples	Mean	Standard Deviation	Standard Error (SE)	SE as % of Mean	Confidence Limit*
White sweetclover	4	5.8	1.09	0.55	9.5	1.8
Yellow sweetclover	4	5.5	1.49	0.75	13.6	2.4
Alfalfa	4	5.5	0.96	0.48	8.7	1.5
Brome	4	3.1	0.51	0.26	8.4	0.8

*At the 0.95 level.

Table 3.3 Copper Levels (µg/g) in Forage Plants Growing on Coal Spoils in the Estevan Area. (Detailed data can be found in Appendix A.)

Species	No. of Samples	Mean	Standard Deviation	Standard Error (SE)	SE as % of Mean	Confidence Limit*
Crested wheatgrass	2	2.6	0.15	0.11	4.2	1.4
Alfalfa	2	6.0	0.42	0.30	5.0	3.8
White sweetclover	2	5.6	1.84	1.30	23.2	16.5
Yellow sweetclover	4	5.9	0.78	0.55	9.3	7.0

*At the 0.95 level.

Table 3.4 Molybdenum Levels (µg/g) in Forage Plants Growing on Coal Spoils in the Bienfait Area. (Detailed data can be found in Appendix A.)

Species	No. of Samples	Mean	Standard Deviation	Standard Error (SE)	SE as % of Mean	Confidence Limit*
Brome	4	3.7	0.70	0.35	9.5	1.1
Crested wheatgrass	4	2.5	0.58	0.29	11.6	0.9
Yellow sweetclover	4	7.9	1.42	0.71	9.0	2.3
Russian wildrye	4	2.0	0.58	0.29	14.5	0.9

*At the 0.95 level.

Table 3.5 Molybdenum Levels (µg/g) in Forage Plants Growing on Coal Spoils in the Roche Percee Area. (Detailed data can be found in Appendix A.)

Species	No. of Samples	Mean	Standard Deviation	Standard Error (SE)	SE as % of Mean	Confidence Limit*
White sweetclover	4	13.8	7.5	3.8	27	12.1
Yellow sweetclover	4	7.8	1.65	0.83	10.6	2.6
Alfalfa	4	4.2	1.16	0.58	13.8	1.8
Brome	4	2.7	0.10	0.05	1.9	0.2

*At the 0.95 level.

Table 3.6 Molybdenum Levels (µg/g) in Forage Plants Growing on Coal Spoils in the Estevan Area. (Detailed data can be found in Appendix A.)

Species	No. of Samples	Mean	Standard Deviation	Standard Error (SE)	SE as % of Mean	Confidence Limit*
Crested wheatgrass	2	2.1	0.22	0.15	5.2	1.9
Alfalfa	2	2.9	0.23	0.16	5.5	2.0
White sweetclover	2	6.1	5.23	3.68	60.3	46.7
Yellow sweetclover	4	5.5	4.86	3.42	62.2	43.4

*At the 0.95 level.

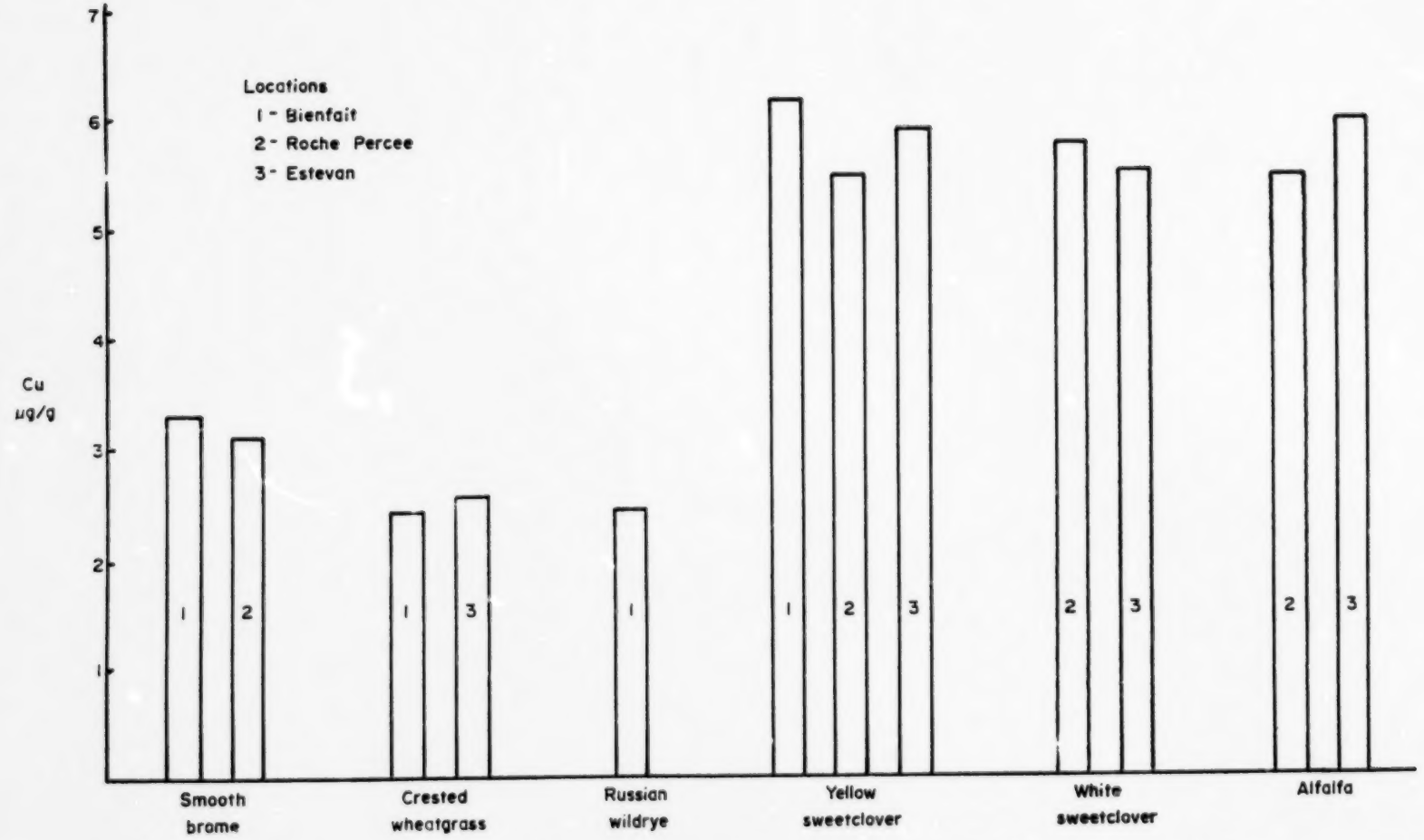


Figure 3.1 Copper Concentration in the Various Plant Species Sampled at Three Locations.

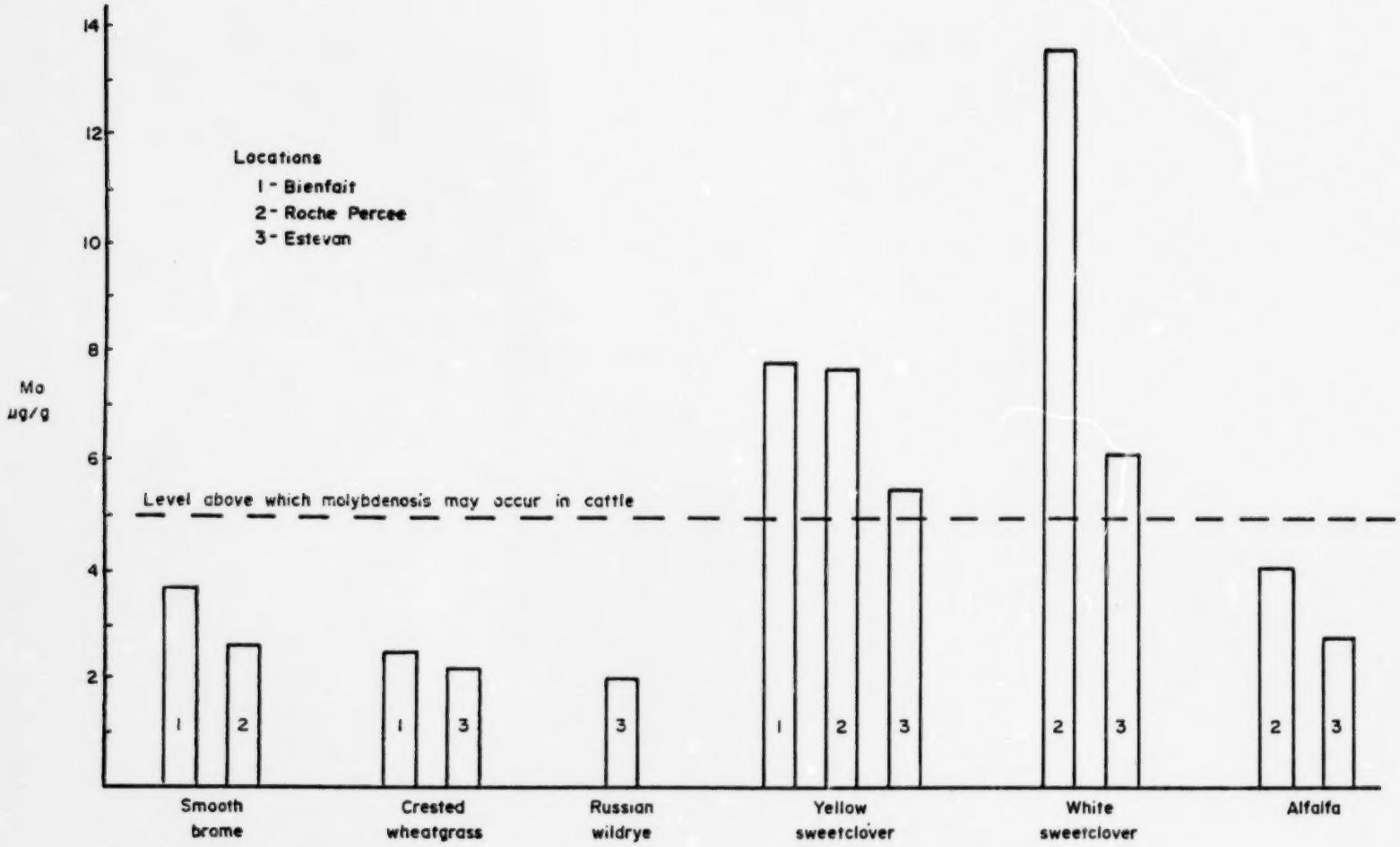


Figure 3.2 Molybdenum Concentration in the Various Plant Species Sampled at Three Locations.

Legumes showed, in general, higher Mo levels than grasses. However, statistically significant differences were found only at the Roche Percee and Bienfait locations.

Webb and Atkinson (1965) reported that 5 µg/g Mo in forage is the approximate upper level tolerated by cattle. In this study, both white and yellow sweetclover exhibited levels in excess of 5 µg/g thus indicating the potential for toxicity (molybdenosis) (Figure 3.2). It has been suggested that molybdenosis is related more to the ratio of Cu to Mo rather than Mo concentration alone. Ratios of Cu to Mo of less than 2:1 will most likely cause molybdenosis symptoms to develop (Dollahite et al. 1972). In the present study, the Cu:Mo ratio was generally less than 2:1 (Figure 3.3). The only exception was alfalfa from the Estevan area where the ratio was 2.1:1. Generally, it can be seen that the problem is more pronounced for the Roche Percee area, particularly in the case of yellow and white sweetclover.

3.3 Spoil Characteristics

Spoil characteristics are given in Table 3.7 for the three locations sampled. The levels of available soil copper are adequate for plant growth at the three locations. The levels were similar for the Bienfait and Estevan areas, but were relatively low for the Roche Percee location. The levels found in this study are somewhat higher than those reported for agricultural soils in east central Saskatchewan by Stewart et al. (1979).

No pronounced correlation was found between the Cu levels in soils and Cu concentrations in plants (Figure 3.4). Although the DTPA test

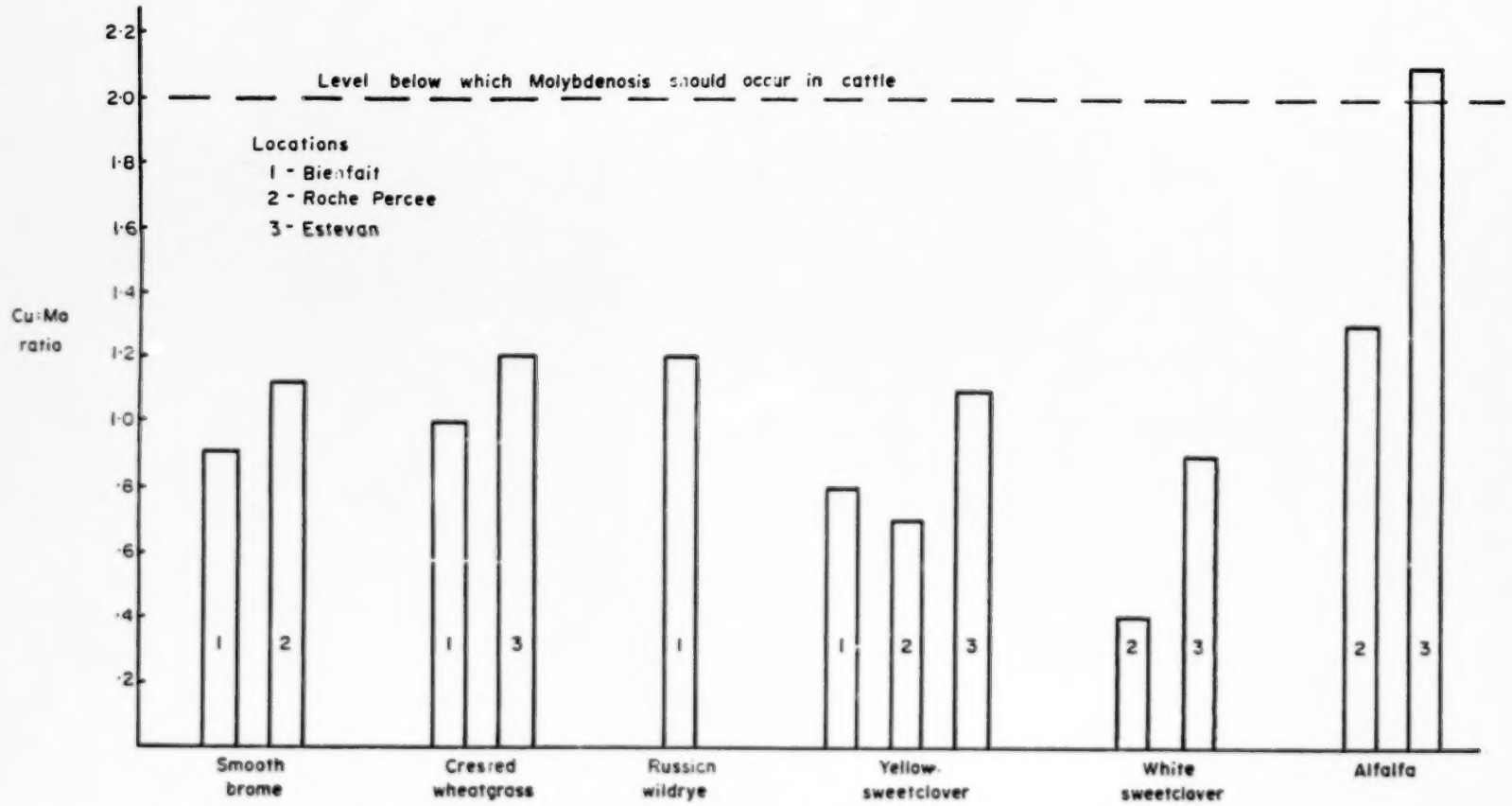


Figure 3.3 Cu:Mo Ratio in the Various Plant Species Sampled at Three Locations.

Table 3.7 Selected Characteristics of Spoil Material from the Locations Sampled. (Detailed data can be found in Appendices B and C.)

Location Parameter	No. of Samples	Mean	Standard Error (SE)	SE as % of Mean	Confidence Limit*
Bienfait					
pH	10	8.0	0.05	0.6	0.11
Texture	10		Loam - Silty Loam		
Copper (µg/g)	10	2.50	0.24	9.6	0.54
Molybdenum (µg/g)	10	0.35	0.05	14.3	0.11
Roche Percee					
pH	8	8.1	0.07	0.9	0.16
Texture	8		Silty Loam - Clay Loam		
Copper (µg/g)	8	1.55	0.18	11.6	0.43
Molybdenum (µg/g)	8	0.83	0.10	12.0	0.24
Estevan					
pH	6	8.3	0.04	0.5	0.10
Texture	6		Silty Loam - Clay		
Copper (µg/g)	6	2.57	0.28	10.9	0.72
Molybdenum (µg/g)	6	0.22	0.02	9.1	0.05

*At the 0.95 level.

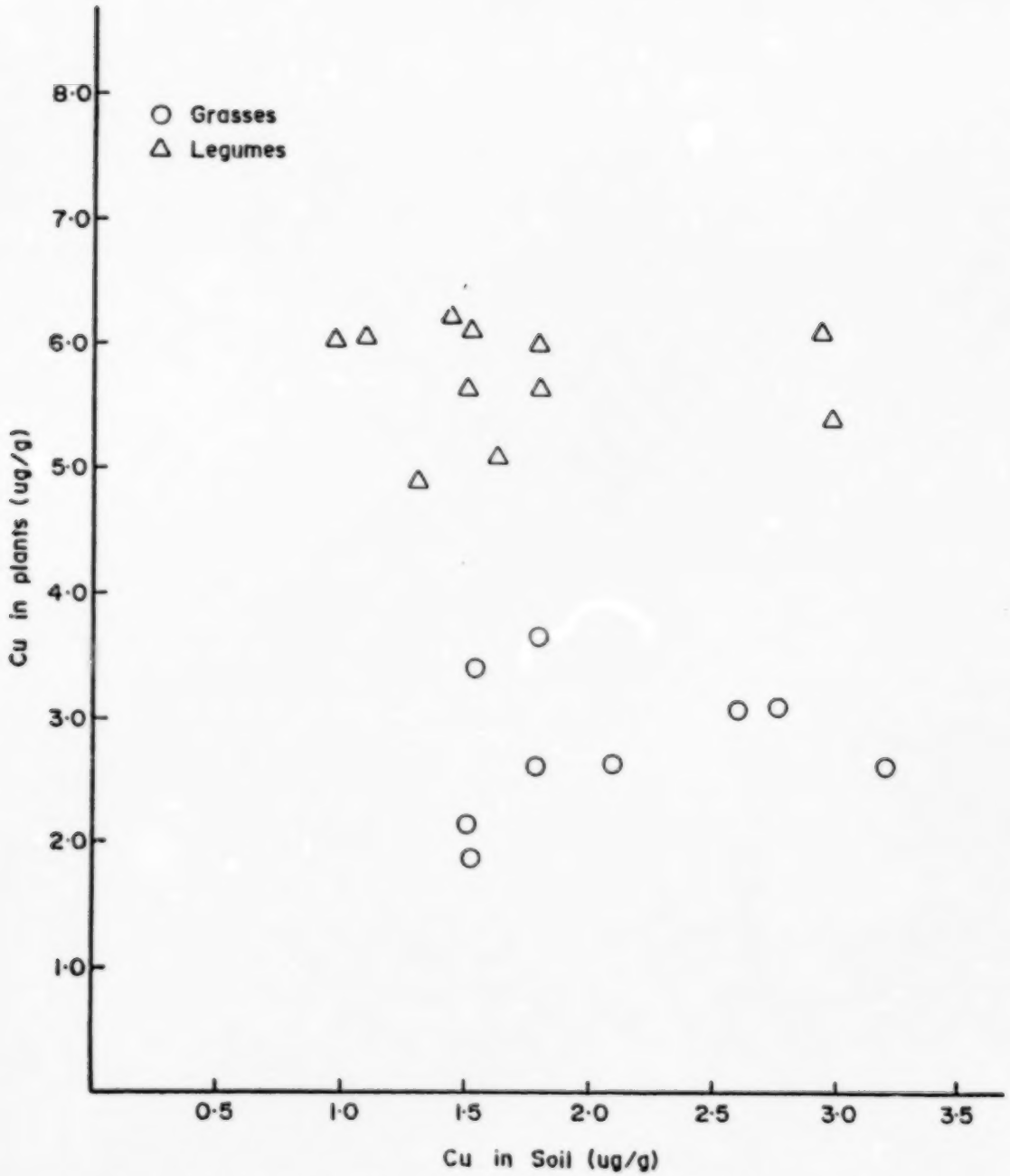


Figure 3.4 Copper Concentration in Plants in Relation to Available Soil Copper Levels.

employed in this study appeared to be superior to other methods when used for evaluation of agricultural soils (Eldin et al. 1983), it may not be the appropriate test for coal spoils. However, it appears from the data that legumes are able to accumulate more Cu in their tissues than grasses.

Most Cu concentrations in plants obtained in this study are much lower than those reported for forage plants grown in nonmined soils in Saskatchewan (Stewart et al. 1979). These differences were not totally unexpected and are likely related to differences in such factors as soil pH, soil moisture and plant species.

The levels of available Mo in the spoil material analyzed in this study are not toxic to plants. Hallaway (1968) indicated that in most plants, no injury takes place at Mo concentrations as high as 100 µg/g. In this study, Mo levels ranged from 0.22 µg/g to 0.83 µg/g (Table 3.7).

The Mo levels were somewhat similar for the Bienfait and Estevan areas. The levels at Roche Percee were substantially higher than the other two locations. The levels obtained for the Bienfait and Estevan areas are within the ranges reported for agricultural soils in the province (Stewart et al. 1979); while the levels from the Roche Percee area are substantially higher than those from nonmined agricultural areas.

In general, no pronounced correlation was found between Mo levels in plants and those in the spoil material (Figure 3.5). However, it is noted that white sweetclover showed a strong linear response to changes in available soil Mo levels.

Most of the plant Mo concentration values obtained in this study are greater than those reported by Stewart et al. (1979). This is per-

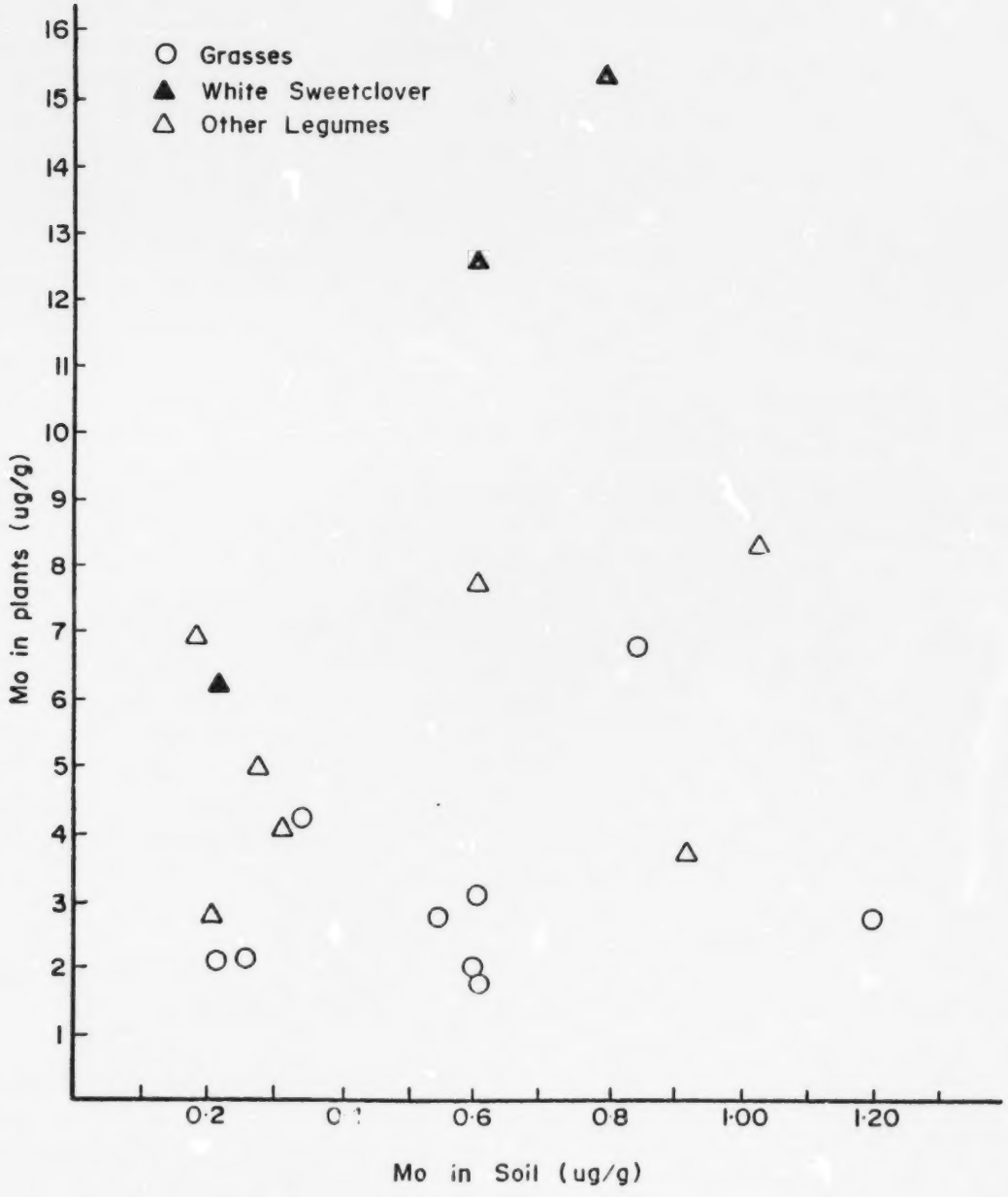


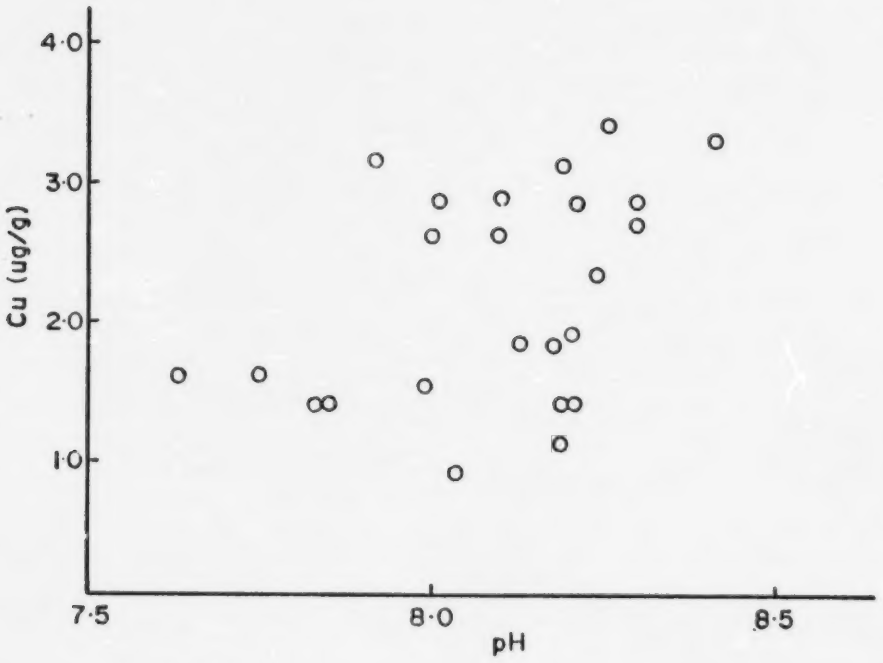
Figure 3.5 Molybdenum Concentration in Plants in Relation to Available Soil Molybdenum Levels.

haps related to differences in soil characteristics (e.g. pH, available moisture) and plant factors.

Soil pH appears to influence the uptake of Mo and Cu by plants (e.g. Erdman et al. 1978). In this study, however, the pH of spoil materials did not seem to influence the uptake of Mo or Cu by plants (Figure 3.6). This is probably due to the narrow pH range found in this study. All spoil materials tested were slightly to moderately alkaline with pH between 7.6 and 8.4. Erdman et al. (1978) dealt with spoil material ranging from 6.2 to 8.2.

As indicated earlier (Section 3.2), the Cu:Mo ratio was lower for plants growing on the Roche Percee spoil material than those from the other two locations. This appears to be related to the relatively low Cu and relatively high Mo found in the Roche Percee spoil material.

The low Cu:Mo ratios for sweetclover found in this study compare well with those reported by Erdman et al. (1978) for ten sites located mainly in North Dakota and Montana.



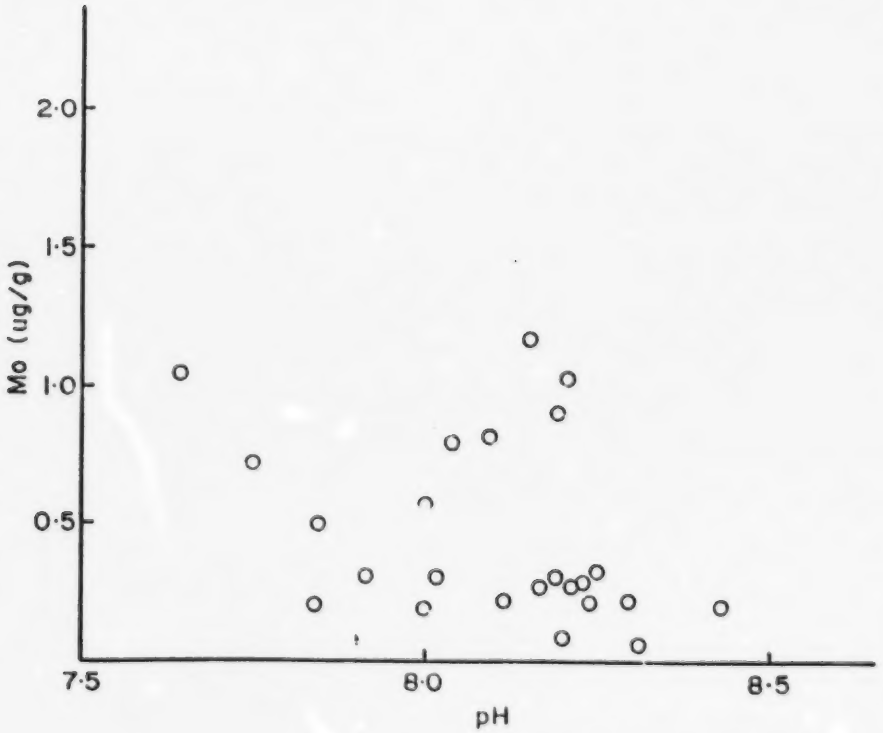


Figure 3.6 Relationship Between Soil pH and Available Soil Cu and Mo.

4 CONCLUSIONS

Copper levels in forage plants growing on coal spoils varied with species. Leguminous species showed generally higher levels than grasses. The Cu content values reported here are generally lower than those of forage plants growing on nonmined agricultural land and are near or below the minimum cattle nutritional levels.

Molybdenum levels in legumes were higher than those of grasses. Both white and yellow sweetclover exhibited levels exceeding the upper level tolerated by cattle. Furthermore, the high Mo levels combined with the low Cu levels resulted in abnormally low Cu:Mo ratios, generally less than 2:1. Ratios of less than 2:1 are likely to cause metabolic imbalances (molybdenosis) to develop in cattle. Characteristic symptoms of molybdenosis in cattle include scouring, weight loss, depigmentation and reproductive impairment. The actual practical significance of the findings of this study is not known, but would depend on such factors as species composition of the pasture or hay crop, length of time the animals are fed solely on forages from reclaimed spoil areas, sulphate content of forage, and chemical composition (e.g. Cu and Mo content) of supplemental feed used.

Planning for revegetation of coal spoils should recognize the potential problem and attempt to minimize it through such means as avoiding the use of Mo accumulating species. Other means to overcome the potential problem include integration of the use of reclaimed areas with adjacent undisturbed areas and use of trace-mineralized salt containing adequate levels of copper.

Cu levels in spoil materials are adequate for plant growth. Al-

though Mo levels in spoil materials are abnormally high at one site, Roche Percee, they are not toxic to plants.

In general, no pronounced correlation was found between Mo or Cu levels in plants and available Mo or Cu in the soil. The main exception is the strong correlation between Mo concentration in white sweetclover and available Mo level in the spoil material.

The present study involved the sampling of six forage species collected on only one occasion from three sites. Therefore, further studies are required before firm conclusions and detailed recommendations can be made.

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APPENDICES

Appendix A. Copper and Molybdenum Levels in Plants.

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SASKATCHEWAN RESEARCH COUNCIL

Environment Sector, SRC
30 Campus Drive
Saskatoon, Saskatchewan S7N 0X1
Attn: Z. Abousuendia, E901-4

Date Samples Received: 12-Aug-83 Client P.O.:

SAMPLE	CLIENT DESCRIPTION
6162	1 CWG ROW 4 *VEGETATION*
6163	2 YSC ROW 2 *VEGETATION*
6164	3 BROME ROW 8 *VEGETATION*
6165	4 BROME ROW 8 *VEGETATION*

ANALYTE	UNITS	6162	6163	6164	6165
TRACE METALS					
Cu, by A.A.	ug/g	2.3	6.0	3.3	3.0
Mo, by A.A.	ug/g	2.0	9.3	4.3	4.3

SAMPLE	CLIENT DESCRIPTION
6166	5 BROME ROW 2 *VEGETATION*
6167	6 BROME ROW 2 *VEGETATION*
6168	7 CWG ROW 2 *VEGETATION*
6169	8 CWG ROW 4 *VEGETATION*

ANALYTE	UNITS	6166	6167	6168	6169
TRACE METALS					
Cu, by A.A.	ug/g	3.7	3.2	1.9	2.8
Mo, by A.A.	ug/g	3.0	3.2	2.0	3.1

SAMPLE	CLIENT DESCRIPTION
6170	9 CWG ROW 4 *VEGETATION*
6171	10 YSC ROW 2 *VEGETATION*
6172	11 YSC ROW 2 *VEGETATION*
6173	12 YSC ROW 2 *VEGETATION*

ANALYTE	UNITS	6170	6171	6172	6173
TRACE METALS					
Cu, by A.A.	ug/g	2.8	7.1	5.7	5.8
Mo, by A.A.	ug/g	2.9	6.7	6.6	8.9

SAMPLE	CLIENT DESCRIPTION
6174	13 RWR ROW 6 *VEGETATION*
6175	14 RWR ROW 2 *VEGETATION*
6176	15 RWR ROW 6 *VEGETATION*
6177	16 RWR ROW 2 *VEGETATION*

ANALYTE	UNITS	6174	6175	6176	6177
TRACE METALS					
Cu, by A.A.	ug/g	2.5	2.4	2.9	1.7
Mo, by A.A.	ug/g	2.7	2.1	1.6	1.4

SAMPLE	CLIENT DESCRIPTION
6178	17 W OF POWER PLANT CWG *VEGETATION*
6179	18 W OF POWER PLANT CWG *VEGETATION*
6180	19 W OF POWER PLANT ALF *VEGETATION*
6181	20 W OF POWER PLANT ALF *VEGETATION*

ANALYTE	UNITS	6178	6179	6180	6181
TRACE METALS					
Cu, by A.A.	ug/g	2.7	2.5	6.3	5.7
Mo, by A.A.	ug/g	2.2	1.9	3.0	2.7

SAMPLE	CLIENT DESCRIPTION
6182	21 W OF POWER PLANT WSC *VEGETATION*
6183	22 W OF POWER PLANT WSC *VEGETATION*
6184	23 E OF POWER PLANT YSC *VEGETATION*
6185	24 E OF POWER PLANT YSC *VEGETATION*

ANALYTE	UNITS	6182	6183	6184	6185
TRACE METALS					
Cu, by A.A.	ug/g	4.3	7.0	4.9	5.8
Mo, by A.A.	ug/g	2.4	9.8	9.7	4.2

SAMPLE	CLIENT DESCRIPTION				
6186	25 E OF POWER PLANT ALF *VEGETATION*				
6187	26 E OF POWER PLANT ALF *VEGETATION*				
6188	27 ROCHE PERCEE #1 WSC *VEGETATION*				
6189	28 ROCHE PERCEE #1 WSC *VEGETATION*				

ANALYTE	UNITS	6186	6187	6188	6189
TRACE METALS					
Cu, by A.A.	ug/g	6.3	6.7	5.6	5.6
Mo, by A.A.	ug/g	3.8	4.3	14	11

SAMPLE	CLIENT DESCRIPTION				
6190	29 ROCHE PERCEE#1 YSC *VEGETATION*				
6191	30 ROCHE PERCEE #1 YSC *VEGETATION*				
6192	31 ROCHE PERCE #1 ALF *VEGETATION*				
6193	32 RP #1 ALF *VEGETATION*				

ANALYTE	UNITS	6190	6191	6192	6193
TRACE METALS					
Cu, by A.A.	ug/g	5.2	4.4	4.2	5.7
Mo, by A.A.	ug/g	7.8	8.9	4.0	5.8

SAMPLE	CLIENT DESCRIPTION				
6194	33 ROCHE PERCEE #1 BROME *VEGETATION*				
6195	34 ROCHE PERCEE #1 BROME *VEGETATION*				
6196	35 RP #1 WSC *VEGETATION*				
6197	36 RP #2 WSC *VEGETATION*				

ANALYTE	UNITS	6194	6195	6196	6197
TRACE METALS					
Cu, by A.A.	ug/g	3.2	2.4	7.3	4.7
Mo, by A.A.	ug/g	2.6	2.7	24	6.3

SAMPLE	CLIENT DESCRIPTION
6198	37 RP #2 YSC *VEGETATION*
6199	38 RP #2 YSC *VEGETATION*
6200	39 RP #2 ALF *VEGETATION*
6201	40 RP #2 ALF *VEGETATION*

ANALYTE	UNITS	6198	6199	6200	6201
TRACE METALS					
Cu, by A.A.	ug/g	7.7	4.3	5.7	6.5
Mo, by A.A.	ug/g	8.9	5.4	4.2	3.0

SAMPLE	CLIENT DESCRIPTION
6202	41 RP #2 BR *VEGETATION*
6203	42 RP #2 BR *VEGETATION*

ANALYTE	UNITS	6202	6203
TRACE METALS			
Cu, by A.A.	ug/g	3.3	3.6
Mo, by A.A.	ug/g	2.6	2.8

Appendix B. Copper and Molybdenum Levels in Coal Spoil Materials.

SASKATCHEWAN SOIL TESTING LABORATORY
SPECIAL ANALYSIS
Abouguendia/Godwin

DATE:05/02/84
D:GDWNSRC-MIC.I83-6414/6437

SAMPLE #	CLIENT SAMPLE NUMBER	Cu ug/ge	Mo ug/ge
I83-6414	BR2 YSCB	1.62	0.74
I83-6415	BR2 YSCBR	1.40	0.50
I83-6416	BR4	3.40	0.31
I83-6417	BR4 CWG	2.96	0.23
I83-6418	BR5 SWG	3.10	0.31
I83-6419	BR5 SWG	2.66	0.21
I83-6420	BR6	2.88	0.29
I83-6421	BR6 RWR	1.42	0.22
I83-6422	BR8	2.34	0.32
I83-6423	BR8 SWG	3.20	0.35
I83-6424	PPW	1.84	0.20
I83-6425	PPW 1	1.78	0.24
I83-6426	PPE ALF	2.94	0.24
I83-6427	PPE ALF 1	2.90	0.27
I83-6428	PPE SC	2.72	0.16
I83-6429	PPE SC 1	3.26	0.20
I83-6430	RPS1 ALF	1.32	0.27
I83-6431	RPS1 BR	2.62	0.84
I83-6432	RPS1 WSC	1.56	0.60
I83-6433	RPS1 YSC	1.62	1.03
I83-6434	RPS2 ALF	1.10	0.92
I83-6435	RPS2 BR	1.82	1.20
I83-6436	RPS2 YSC	1.46	1.01
I83-6437	UN 1	0.98	0.79

COMMENT: D.T.P.A. - extractable Cu
Anion-exchange resin-extractable Mo

Appendix C. pH and Texture of Coal Spoil Materials.

Sample	pH	Texture
BR2YSCB	7.8	Silty loam
BR2YSCBR	7.8	Loam
BR4	8.2	Loam
BR4 CWG	8.1	Loam
BR5 SWG	8.2	Silty loam
BR5 SWG	8.0	Silty loam
BR6	8.0	Loam
BR6 RWR	7.8	Loam
BR8	8.2	Silty loam
BR8 SWG	7.9	Loam
PPW	8.2	Silty loam
PPW1	8.2	Silty loam
PPE A1f	8.3	Clay
PPE A1f1	8.2	Clay
PPE SC	8.3	Clay
PPE SC1	8.4	Clay
RPS1 A1f	8.2	Silty loam
RPS1 BR	8.1	Clay loam
RPS1 WSC	8.0	Silty loam
RPS1 YSC	7.6	Silty loam
RPS2 A1f	8.2	Silty loam
RPS2 BR	8.2	Clay loam
RPS2 YSC	8.2	Clay loam
RPS2 WSC	8.0	Sandy loam